PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H05B 41/29 — A1

(11) International Publication Number: WO 97/43879

(43) International Publication Date: 20 November 1997 (20.11.97)

(21) International Application Number: PCT/IB97/00482

(22) International Filing Date: 5 May 1997 (05.05.97)

(30) Priority Data:
08/645,545 10 May 1996 (10.05.96) US

(71) Applicant: PHILIPS ELECTRONICS N.V. [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL).

(71) Applicant *(for SE only)*: PHILIPS NORDEN AB [SE/SE]; Kottbygatan 7, Kista, S-164 85 Stockholm (SE).

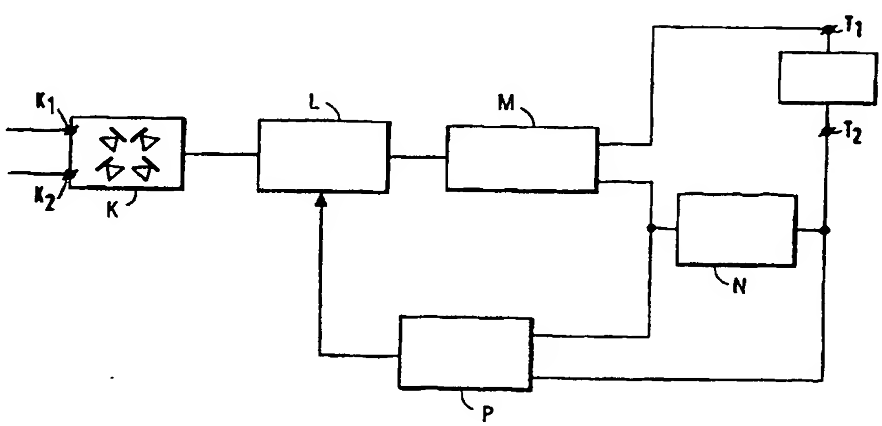
(72) Inventors: VENKITASUBRAHMANIAN, Sreeraman; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). MASON, Clint; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). XIA, Yong-Ping; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). HU, Feng-Kang; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). SCHLEJEN, Jacob; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).

(74) Agent: EVERS, Johannes, H., M.; Internationaal Octrooibureau B.V., P.O. Box 220, NL-5600 AE Eindhoven (NL).

(81) Designated States: CN, JP, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: POWER SUPPLY FOR FEEDING AND IGNITING A GAS DISCHARGE LAMP



(57) Abstract

A power supply for feeding and igniting a gas discharge lamp according to the invention comprises ballasting means (K, L, M, N) for providing an AC voltage to maintain a column discharge between the discharge electrodes of a discharge lamp alternately with one polarity and with the opposite polarity at a frequency substantially higher than the mains supply frequency. The power supply further comprises end of life detection means (P) for detecting an asymmetric operating state of the lamp in which the lamp current for the column discharge of one polarity is different from the lamp current for the column discharge of the other polarity, and for switching off the lamp if a said asymmetric operating state is detected. The end of life detection means comprise DC-voltage detection means (VD) for detecting a deviation of a DC-voltage from a nominal value due to a said asymmetric operating state. The end of life detection means (P) further comprise timer means (Ti) which switch off the lamp if a deviation is detected for a time duration longer than a threshold time value.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

Power supply for feeding and igniting a gas discharge lamp.

The invention relates to a power supply for feeding and igniting a gas discharge lamp, said power supply comprising:

a) input terminals for connection to an AC mains supply having a mains supply frequency,

b) output terminals for connection to a gas discharge lamp having a pair of discharge electrodes between which a column discharge is maintainable during lamp operation,

c) ballasting means connected between said input terminals and said output terminals, said ballasting means providing an AC voltage at said output terminals to maintain a column discharge between the discharge electrodes of the discharge lamp alternately with one polarity and with the opposite polarity at a frequency substantially higher than the mains supply frequency, and

d) end of life detection means for detecting an asymmetric operating state of the lamp in which the lamp current for the column discharge of one polarity is different from the lamp current for the column discharge of the other polarity, and for switching off the lamp if a said asymmetric operating state is detected, which end of life detection means comprise DC-voltage detection means for detecting a deviation of a DC-voltage from a nominal value due to a said asymmetric operating state.

Such a ballast is known from US 5 475 284. During lamp operation, ballasts for gas discharge lamps commonly provide an AC voltage across the lamp so that the lamp current is alternating and a column discharge is maintained between the lamp electrodes during both the positive and negative half-cycles of the AC output voltage. During the positive half-cycle one electrode is the cathode and the other is the anode. The electrodes assume the opposite function for the negative half-cycle. When an electrode is the cathode it emits electrons to ignite and maintain the column discharge during the respective half-cycle. The electrodes typically include an electron emissive material which provides an ample supply of electrons when the electrode is the cathode. During lamp life, the discharge

electrodes age and lose emitter material through known processes, typically at a slightly different rate. Consequently, it is common for the lamp to reach an end-of-life condition in which one of the electrodes, when the cathode, is unable to supply sufficient electrons to ignite and maintain the column discharge, which results in a column discharge being maintained during only the negative or positive half cycles of the AC output voltage. In this half-wave discharge condition, the lamp essentially acts as a rectifier.

The above-mentioned JP 1-251591 discloses that the non-discharging voltage of the lamp is higher than the discharging voltage, resulting in the amplitude of the AC voltage across both ends of the lamp being higher than during normal operation. JP 1-251591 includes a detection circuit which measures the AC voltage across the lamp, and detects the occurrence of the higher AC voltage when the lamp is in the half-wave condition.

As the emissive material is depleted from one of the electrodes, the cathode fall voltage of the lamp increases which raises the temperature of the electrode region and the glass of the lamp envelope in the seal adjacent the electrode. In this partially rectifying condition, the increase in temperature can cause rupture of the lamp vessel before the full half-wave condition is reached, and even before any visible flicker occurs. This applies in particular to narrow diameter lamps. The change in the AC voltage across the lamp is too small to reliably detect this partially rectifying condition. Detection is complicated by the fact that the difference in AC lamp voltage between lamps of the same type from different manufactures, as well as the variation with ambient temperatures, is often larger than the change in AC lamp voltage for a particular lamp between the normal and full half-wave condition. The change in the DC voltage across the lamp, however, is larger and can more reliably be detected.

US-5 475 284 discloses a ballast provided with an invertor feeding a load circuit comprising a fluorescent lamp and provided with means that switch off the invertor when the deviation from the nominal value (0 V) of the DC-voltage over the lamp exceeds a threshold value. Hereinafter a deviation of a DC-voltage from its nominal value will also be referred to as voltage deviation. Also during ignition of the lamp a voltage deviation may occur over the lamp even if the lamp has not approached end of life. Consequently the threshold value has to be relatively high in order to prevent that a new lamp is already switched off during ignition. This restricts however the sensitivity with which the detection means can detect an end of life condition of the lamp.

It is an object of the invention to provide a ballast which render possible a higher sensitivity of the detection means.

According to the invention, a ballast of the type described in the opening paragraph is characterized in that the end of life detection means further comprise timer means which detect an asymmetric operating state if the DC-voltage detection means detect a deviation of the DC voltage from its nominal value for a time duration longer than a threshold time value. Lamp ignition only lasts a relatively short time, while the end of life condition is approached gradually. The threshold time value is selected to be above the expected time that a voltage deviation occurs in a "good" lamp during ignition. Because in the ballast of the present invention it is detected whether a voltage deviation is detected for longer than a first time threshold, the invertor will not be switched off even if a voltage deviation occurs. This allows for relatively sensitive DC-voltage detection means. Because of the high sensitivity, the first time threshold can be relatively long without resulting in hazardous situations.

A favorable embodiment of the power supply of the invention is characterised in that the timer means includes means for storing a time value when the DC-voltage is no longer detected and for incrementing the time value when the DC voltage is subsequently detected. This renders possible a further improvement in the sensitivity of the end of life detection means.

An attractive embodiment of the power supply according to the invention is characterised in that the power supply includes reactivation means for re-igniting the lamp within a predetermined time after the threshold time value is exceeded. If on the one hand the lamp was erroneously switched off, for example by noise caused by a transient in the mains, the lamp will normally continue its operation after re-ignition. If on the other hand the lamp has approached end of life, the detection means will after a period corresponding to the time threshold value switch off the lamp again. This has the result that the discharge lamp recurrently extinguishes and ignites with a predetermined dwell time in between, for example of several seconds. This "hiccup" operation serves as an indicator to the user that the lamp needs to be replaced. The time durations during which the lamp is in operative and in non-operative condition can be chosen such that it keeps sufficiently low temperature to prevent hazardous situations.

The DC-voltage detection means may detect a voltage deviation across the lamp itself, in which case the nominal value is 0 V, but it may otherwise be detected

indirectly. For example a device may be coupled to the lamp such that a voltage deviation is reflected there across when the lamp current is different for the column discharge according to one polarity verses the other polarity. The device may be a capacitive device, and in a particularly inexpensive implementation, is a DC blocking capacitor in the ballast which is otherwise normally present to block low level DC components from the lamp during operation. Alternatively, if the ballast includes a current limiting ballast capacitor, the voltage deviation reflected across this ballast capacitor may be detected. In still another embodiment, the voltage deviation generated by asymmetric operation of the lamp is detected in a bridge circuit at an end of a load branch including the discharge lamp.

A favorable embodiment of the power supply of the invention is characterised in that said ballasting means include a DC source having a DC potential, a bridge inverter including a pair of switches series connected across said DC source, a load circuit including output terminals for the discharge lamp, said load circuit having a first end coupled to a node between said switches and a second end, a half bridge supply capacitor coupled to the DC source and said second end of said load circuit, and means for switching said switches to generate an AC signal across the discharge lamp, said switches being switched such that the DC voltage at said second end of said load circuit has a nominal value in a non-asymmetric operating state of the lamp equal to one-half said DC potential, said detection means detecting the voltage deviation generated by said asymmetric operating state of the lamp.

In an implementation of said embodiment the detection means include means for setting a high threshold voltage equal to said nominal value plus a DC threshold value and a low threshold voltage equal to said nominal value minus said DC threshold value, means for comparing the DC voltage at the second end of said load circuit with said high and low threshold voltages, and for outputting a control signal when the DC voltage at said second end of said load circuit is higher than said high threshold voltage or lower than said lower threshold voltage.

Another favorable embodiment of the power supply of the invention is characterised in that the DC-voltage detection means comprise means for determining the magnitude of the voltage deviation from the nominal value and means for comparing said magnitude with a threshold voltage, and for outputting a control signal when said magnitude is higher than said threshold voltage. In this embodiment it suffices to compare the DC-voltage with a single threshold value.

These and other objects, features and advantages of the invention will

become apparent with reference to the accompanying drawings and the following detailed description and claims.

In the drawing:

Figure 1 schematically illustrates in simplified form a lamp system including a power supply and fluorescent lamp;

Figure 2 shows the difference in the lamp current waveform between the positive and negative half-cycles for a partially rectifying condition of the lamp which could cause a lamp envelope failure;

Figure 3 is a block diagram of a power supply according to the invention;

Figure 4 illustrates in more detail a portion of the embodiment of Figure 3;

Figure 5A is a block diagram of a second embodiment of a power supply according to the invention;

Figure 5B illustrates in more detail a portion of the embodiment of a Figure 5A; and

Figure 6 illustrates a third embodiment of the power supply according to the invention.

Figure 1 illustrates schematically a lamp system including a low pressure mercury vapor gas discharge lamp 400, commonly known as a fluorescent lamp, and a power supply 300 for igniting and operating the lamp. The power supply 300 includes a current limited AC voltage source, which may be low or high frequency, and which includes capacitor 320 coupled in series with the lamp 400. The lamp includes a pair of tungsten filament electrodes 414 each provided with an electron emissive material having a lower work function than the tungsten, and a discharge sustaining fill of mercury and a rare gas. During operation, a column discharge is maintained between the electrodes 414 during both the positive and negative half-cycles of the AC voltage source. When an electrode 414 is the cathode it emits electrons to ignite and maintain the column discharge during the respective half-cycle. Over lamp life, the electron emissive material is depleted from the electrodes, typically at a different rate for each electrode. This depletion is manifested by darkening of the lamp envelope in the area of the electrodes. As the emissive material nears full depletion,

the tungsten material emits more electrons to support the discharge. Since the tungsten material has a higher work function, the cathode fall voltage increases. This causes an increase in temperature of the electrode region, with a consequent increase in temperature in the seal area 412. In effect, the increased cathode full voltage causes the lamp to consume more power, with the additional power being dissipated in the form of heat at one end of the lamp. If lamp operation were to continue in this manner, there is the possibility that the lamp envelope could fail, even violently.

The imbalance between the electrodes effects the shape of the lamp current waveform.

Failure-causing overheating of the lamp envelope often occurs well before the fully rectified condition is reached, when the difference in the lamp current waveform between the positive and negative half-cycles is much smaller than for the fully rectified condition. Figure 2 shows the typical lamp current waveform for a partially rectifying condition which was found to cause lamp envelope failure. The magnitude of the positive and negative half-cycles is essentially the same. The only difference is that the shape of the negative half-cycle near the crest (see ref. arrow A) is different from the shape of the positive half-cycle. This minor difference in the waveform makes it impractical to use either the AC lamp current or the resulting AC voltage to detect this partially rectifying condition.

However, the difference in the lamp current causes a DC voltage across the lamp with a magnitude, both in absolute terms and as a percentage of the nominal lamp voltage, which is much easier to detect. In Figure 1, the arrows diagrammatically represent the lamp current and the meters 500, 510 illustrate the DC lamp voltage. When the lamp current for both half cycles is at least substantially equal as represented by the arrows with solid lines, for example in a relatively new lamp, there is no or almost no DC voltage across the lamp. However, with an aged lamp in a partially rectifying condition (as represented by the dashed arrows), the product of the lamp impedance and the small differences in the lamp current waveform produces a DC voltage across the lamp (as indicated by the dashed needle on meter 500) which is easily detectable. For example, in a 26 W lamp, this DC voltage varies between 0 V for a new lamp and about 30 V for a lamp near end of life, as compared to a nominal lamp voltage of about 80 V AC.

This DC voltage can be measured in numerous ways. A very convenient circuit utilizes the reflection of the lamp voltage on other circuit components. As illustrated in Figure 1, a DC voltage equal to the DC voltage across the lamp is reflected across the capacitor 320 connected in series with the lamp, as indicated by the meter 510. Depending

on the ballast design, this capacitor could be a current limiting ballast capacitor or a DC blocking capacitor.

Figure 3 is a block diagram of a first embodiment of the power supply of the invention. The power supply shown in Figure 3 has input terminals K1, K2 for connection to an AC mains supply having a mains supply frequency. The power supply further has output terminals T1, T2 for connection to a gas discharge lamp having a pair of discharge electrodes between which a column discharge is maintainable during lamp operation. The power supply may have further output terminals for further discharge lamps. Ballasting means are connected between the input terminals and the output terminals. The ballasting means provide an AC voltage at the output terminals to maintain a column discharge between the discharge electrodes of the discharge lamp. The voltage alternates with one polarity and with the opposite polarity at a frequency substantially higher than the mains supply frequency. In the embodiment shown the ballasting means include an EMI and triac damping filter "A", a full bridge input rectifier "B", a pre-conditioner circuit "C", a ballast circuit "D" including a DC-AC convertor, or invertor "E", resonant tank output circuit "F" and controller "G" which controls the inverter E.

The full bridge input rectifier "B" and the EMI and triac damping filter "A" connected thereto, together convert an AC power line voltage into a rectified, filtered DC voltage at pre-conditioner circuit "C". The latter includes circuitry for active power factor correction, as well as for increasing and controlling the DC voltage from the rectifier circuit B, which DC voltage is provided across a pair of DC rails RL1, RL2. Circuit "D" controls operation of the lamp. The inverter E is for example a half-bridge configuration which under control of the half-bridge controller, or driver. The inverter E provides a high frequency substantially square wave output voltage to the output circuit F. The resonant tank output circuit F converts the substantially square wave output of the half-bridge into a sinusoidal lamp current.

The safety circuit "H" is provided with switch off means (not shown) which prevents an output voltage from being present at the lamp terminals when one or more fluorescent lamps connected to the power supply have failed or have been removed from their socket. The safety circuit also restarts the controller G when its senses that both filament electrodes in each lamp are good. The safety circuit is further provided with end of life detection means for detecting an asymmetric operating state of the lamp in which the lamp current for the column discharge of one polarity is different from the lamp current for the column discharge of the other polarity. The end of life detection means serve to switch

off the lamp if an asymmetric operating state is detected. The end of life detection means comprise DC-voltage detection means for detecting a deviation of a DC-voltage from a nominal value due to an asymmetric operating state of the lamp. The end of life detection means further comprise timer means which detect an asymmetric operating state if a voltage deviation is detected for a time duration longer than a threshold time value.

A dimming interface circuit "I" is connected between an output of the preconditioner "C" and a control input of ballast circuit present at the controller G to control dimming of the lamp. The dimming interface circuitry provides a dimming voltage signal to the controller G which is proportional to the setting of the phase angle dimmer. Such a ballast is known from and fully described in U.S. application serial No. 08/414,859 filed March 31, 1995 entitled "Electronic Ballast With Interface Circuitry for Phase Angle Dimming Control", now U.S. Patent 5 559 395, herein incorporated by reference.

Figure 4 shows the DC-voltage detection means of the embodiment of Figure 3 in more detail. The DC blocking capacitor C25, the transformer T4, the power supply transformer T2, the inverter switches Q2 and Q3, and the integrated circuit IC U4 are the same as those shown in Fig. 2 of U.S. 5 559 395. The end of life detection means "J" include DC voltage detection means "VD" which activates a control circuit formed by the optocoupler O1, which on its turn activates timer means "Ti". The timer means detect an asymmetric operating state of the lamp and cause the end of life detection means to switch off the lamp if a deviation from the nominal value (0 V) of the DC-voltage over the blocking capacitor C25 is detected for a time duration longer than a threshold time value.

The DC-voltage detection means include a breakdown device in the form of a pair of zener diodes D25, D26 and a resistor R40 in series with the input terminals of the optocoupler, all connected in series across the DC blocking capacitor C25. Any DC components generated by the lamp in either direction are blocked by and are reflected across the DC blocking capacitor C25. The DC blocking capacitor C25 is otherwise present to block low level DC components generated in a "good" lamp which would adversely affect the operation of the output transformer T4. In Fig. 4, the zener diodes D25, D26 are each rated at 25 V. The resistor R40 functions to limit the current into the input terminals of the optocoupler, to a current suitable for the optocoupler, once the zener diodes breakdown in response to their combined breakdown voltage appearing across the DC blocking capacitor C25.

During normal operation, the lamp current during the positive half-cycle is substantially the same as during the negative half-cycle of the AC output voltage. Thus, an

essentially balanced condition exists for the lamp current. As a result, the DC component of the voltage across each lamp is very small. Consequently the deviation from the nominal value of the DC-voltage across the DC blocking capacitor C25, is insufficient to cause the zener diodes D25, D26 to breakdown. However, as the lamp current becomes asymmetric in one of the lamps, as shown in Figure 2, the DC component of the lamp voltage will no longer be small, and will cause the zener diodes D25, D26 to breakdown. This causes the light emitting diode in the optocoupler to emit light, and close the switch within optocoupler O1, which has one switch terminal connected to ground and the other switch terminal connected to the timer means "Ti", which detect an asymmetric operating state if the voltage deviation is detected for a time duration longer than the threshold time value. The timer means then deactivate the integrated circuit IC U4, which controls the switching of the half-bridge inverter switches Q2, Q3. With IC U4 turned off, the inverter stops oscillating and the lamps are extinguished. By turning off the lamps, damage to ballast components from the lamps operating in an unbalanced condition is avoided. More importantly, catastrophic failure of the lamp envelope due to overheating of the depleted cathode and the surrounding glass is prevented.

The IC U4 includes a dim input (Pin 4, DIM) for receiving a dim signal. The IC U4 controls the switching of switches Q2, Q3 to control the light level of the discharge lamp at a level corresponding to the dim signal. In the embodiment herein incorporated by reference from the above-mentioned US 5 559 395, the dim signal is a voltage supplied by a dim interface circuit receiving the rectified output of a triac dimmer. The dim signal can be supplied in other ways, however, such as directly by a third wire.

During lamp ignition it is possible that there will be asymmetry for a brief period of time even in a "good" lamp, for which it is not desired to shut down the inverter. This may be caused, for example, by the manner in which the electrodes are pre-heated. The timer means "Ti" prevent the ballast from being shutdown in this event. In particular, the timer means measure the time duration that the DC voltage is above the selected threshold voltage. If the time duration exceeds the threshold time value, set longer than the typical ignition time for a "good" lamp, the lamp will be switched off.

A second embodiment of the power supply of the invention is shown in Figures 5A and 5B. In this embodiment the power supply includes reactivation means for igniting the lamp within a predetermined time after the first threshold time value is exceeded. The ballast remains off for said predetermined time, after which ignition is attempted. For a "good" lamp, the lamp will start and operate normally. For a rectifying lamp, the lamp will

ignite and stay lit for a time period corresponding to the threshold time value and then be off during the predetermined time. The lamp will continue to cycle or "hiccup" in this manner, signalling to the user that the lamp needs to be replaced.

Figure 5A is a block diagram of the power supply. The voltage deviation generated by the asymmetric state of the lamp is detected across a ballast capacitor N. The power supply shown has input terminals K1, K2 and output terminals T1, T2. The ballasting means of the power supply of Figure 5A comprise a full wave bridge rectifier "K", a power oscillator "L", a transformer "M", and the ballast capacitor "N". The full wave bridge rectifier "K" provides a DC voltage to a power oscillator "L", from an AC mains voltage at its inputs K1, K2. The power oscillator includes a pair of switches and provides a high frequency AC output voltage to the transformer "M". The discharge lamp is connected to output terminals T1, T2, in series with the ballast capacitor "N" to a secondary winding of the transformer "M". The ballast transformer provides a constant voltage source while the capacitor N limits current to the lamp.

The power supply is provided with end-of-life detection means "P", which are shown fully in Figure 5B.

The heart of the timer means is formed by a 14 stage ripple binary counter CTR. The timer means further comprise semiconductor switches Q20 and Q21, diodes D36 - D39, capacitors C54, C55 and resistors R54 - R59. The timer means measure the time that the DC voltage is above the threshold voltage, control the hiccup operation of the lamp once the threshold is passed, and prevent a good lamp from being shut-off during ignition. The counter CTR is powered by a low voltage supply provided at inputs P1 (ground) and P3, which may be for example a tapped winding of the transformer "M". The zener diode D35 is connected across the inputs 1, 3 in parallel with the capacitor C53, which together provide voltage regulation and filtering. The power input VCC of the counter CTR is connected to input P3. The resistor R58 and the capacitor C55 have an RC time constant which controls the oscillation frequency of an internal oscillator within counter CTR and are connected at respective inputs RTC and CTC. The resistor R58 and capacitor C55 are coupled to ground via pull-down resistor R57 through switch Q21. The internal oscillator only oscillates when switch Q21 is not conducting, i.e. in its OFF state. When switch Q21 becomes conductive (turns "ON"), the oscillator stops oscillating by grounding the RS input. Additionally, whenever power is applied to inputs P1, P3 to turn the counter CTR "ON", the multiple stages of counter CTR are reset to logic 0 by a pulse generated on the node between the resistor R56 and the capacitor C54 and the master reset input MR.

The DC-voltage detection means "Vd" comprise diodes D30 - D33, zenerdiode D34, resistors R50 - R53 and capacitors C50 - C52. The DC voltage is sensed by a pair of sense resistors R50, R51 each connected to a respective end of the ballast capacitor "N". Since the ballast capacitor controls the current through the lamp, the sense resistors are selected to permit detection of the voltage across the ballast capacitor while drawing little current. The other ends of the resistors R50, R51 are connected to a full bridge rectifier consisting of diodes D30, D31, D32 and D33. The bridge rectifier forms means for determining the magnitude of the deviation from the nominal value of the measured DC-voltage. The capacitors C50 and C51 filter the high frequency ripple present on the DC voltage sensed by the resistors R50, R51. The cathode of the zener diode D34 is connected to the output of the full bridge rectifier at the cathodes of D30 and D31. The zener diode D34 has a breakdown voltage selected as a predetermined threshold value for the DC voltage level, and also prevents noise from influencing the operation of the DC-voltage detection means. The zener diode forms means for comparing the afore-mentioned magnitude with a threshold voltage. When the diode D34 breaks down, the switch Q20 transfers the breakdown voltage to a logic level. The base of switch Q20 is connected to the anode of the zener diode D34 via series resistor R52 which limits the current to the base. The emitter of switch Q20 is connected to the anodes of the diodes D32, D33 and to reference ground. The capacitor C52 provides additional filtering. The resistor R53 is a pull down resistor and ensures that the switch Q20 turns off when the detected voltage falls below the threshold voltage. The collector of switch Q20 is connected to input P3 via the resistor R54 and to the base of switch Q21. The switch Q21 serves to invert the logic output of the switch Q20. The switch Q20, the resistors R52, R53 and the capacitor C52 form means for outputting a control signal.

The counter CTR includes a 14 stage binary counter which counts the oscillations of the internal oscillator, whenever the input RS is high. The coupling of the outputs of these stages determines the length of the threshold time value and of the predetermined time for reactivation. In this embodiment, the outputs Q11, Q12, Q13 of the stages 11-13 are logic "OR"ed together via diodes D36, D37, D38. The cathodes of the diodes D36-D37 are connected to ground via the resistor R59, to the control gate of a mosfet switch Q22, which forms switch off means Sw, and to the base of switch Q20 via a resistor R55 and a diode D39 connected in series. The source of the mosfet switch Q22 is connected to the base of switch Q_{L2} of the power oscillator "L" and the drain of switch Q22 is connected to ground. Whenever the output of either of stages Q11, Q12, or Q13 are high,

the output of the counter CTR is high.

The operation of the end of life detection means is as follows. When power is applied to inputs P1, P3 the multiple stages of counter CTR are reset to logic 0. Switch Q20 is normally open and switch Q21 is normally closed, so the internal oscillator of the counter CTR is off. Whenever a DC voltage greater than the threshold voltage is present across the ballast capacitor "N", the zener diode D34 breaks down, closing switch Q20, which opens switch Q21. This causes the internal oscillator to oscillate and the 14 counter stages to count the internal oscillations. If the detected DC voltage across capacitor "N" falls below the threshold voltage, the switch Q20 opens, closing switch Q21 and stopping the internal oscillator of counter CTR. Counter CTR effectively stores the existing count. When the zener diode D34 subsequently breaks down again, switch Q20 closes, opening switch Q21, and restarting the internal oscillator and count of the counter CTR. Thus, the counter effectively integrates the time at which the DC voltage across ballast capacitor "N" exceeds the threshold voltage.

When the logic output Q11 of the 11th stage goes high, the ORed counter output is high. This closes the mosfet switch Q22, which grounds the base of the switch Q_{L2} of oscillator "L", stopping oscillation of oscillator "L" and extinguishing the lamp. The high ORed output applied to the base of switch Q20 through resistor R55 and diode D39 keeps switch Q20 closed and switch Q_{L2} open, thereby keeping the counter CTR counting. Counter CTR keeps counting until the ORed output of stages Q11-Q13 turns low, which signifies the end of the second time period being reached. When the ORed output turns low, both the mosfet switch Q22 and the bipolar switch Q20 open. The latter closes switch Q_{L2}, resetting counter CTR to count 0. Once switch Q22 opens, the base of switch Q_{L2}, is no longer grounded and the inverter ignites and operates the lamp. In one embodiment, the threshold time value was selected as 1.25 seconds and the predetermined time for reactivation as 8.75 seconds. Thus, once a lamp reaches a stage where it rectifies the lamp current so that the resulting DC level is above the threshold value, the lamp will be lit for 1.25 seconds and off for 8.75 seconds. This cycle repeats and signals the user that the lamp needs to be changed.

It should be noted that the threshold time value is selected to be longer than any asymmetry in the lamp current which is expected to be present during ignition of a good lamp and which exceeds the threshold voltage. If such asymmetry occurs during ignition, the counter CTR will begin counting, but the DC voltage across the ballast capacitor will subsequently fall below the threshold value, thereby stopping counter CTR prior to the ORed counter output having turned high. Consequently, counter CTR will stop

counting and the count will remain the same during lamp operation and not turn the lamp off since for a good lamp, the DC voltage will remain below the threshold voltage.

Figure 6 shows a third embodiment of the power supply of the invention. The circuit takes advantage of the reflection of the DC lamp voltage to the midpoint of a bridge inverter in a non-isolated high frequency(HF) ballast, i.e. a HF ballast without an output isolation transformer as in the above-mentioned US 5 559 395. Such a power supply may be used, for example, in a compact fluorescent lamp. In Figure 6, only the relevant portion of the bridge inverter is shown, which in this implementation is half-bridge having a first DC bus RL3 at ground potential and a second DC bus RL4 at a voltage HV+, for example 320V. The buses RL3 and RL4 and a low voltage bus VDD are connected to a AC/DC convertor (not shown) with input terminals for connection to an AC mains supply. The bridge circuit includes a first branch with a pair of (schematically illustrated) switches S1, S2 connected in series across buses RL3, RL4 and a second branch in parallel to the first branch including half-bridge supply capacitors C61, C62 also series connected across buses RL3, RL4. A resonant load branch is connected in series between the midpoints M1, M2 between the capacitors C61, C62 and the switches S1, S2, respectively. The load branch includes lamp L connected at output terminals T1, T2 in series with inductor L10, with filament heating capacitor C63 in parallel with the lamp and in series with the filament electrodes. It should be noted that the ballast capacitors C61, C62 could be replaced by a single ballast capacitor C64 (shown in dotted lines) and having the combined value of capacitors C61 and C62. The DC/AC-convertor and the bridge circuit connected thereto form ballasting means.

Control circuits for driving the switches S1, S2 are well known in the art, and not relevant to the end of life detection means. Consequently they will not be further discussed. In nominal operation with a 50% duty cycle of each of switches S1 and S2, the nominal value of the DC voltage at midpoint M1 is 1/2 HV+. A voltage deviation appearing across the lamp in its rectifying state will be reflected at point M1 as a deviation of the DC-voltage at that point. This can be detected and used to stop inverter oscillation and turn off the lamp.

The end of life detection means employ some of the same components and logic as used in the immediately preceding embodiment. Consequently, components the same as those in Figure 5B share the same reference numerals. A low voltage bus VDD provides power to the counter CTR at terminal VCC. The resistors R61 and R62 are connected in series between the midpoint M1 and ground, and reduce the voltage detected at point M1

sufficiently to protect the remaining components of the detection circuit. The capacitor C65 is connected in parallel with the resistor R62 and forms together with the resistor R62 a low pass filter which filters out the high frequency component of the signal at node M1 caused by the high frequency switching of half-bridge switches S1, S2. The resistors R63, R64 and R65 are connected in series between the VDD bus and ground and form a voltage divider which provides a low threshold voltage at a node between the resistors R64 and R65 and a high threshold voltage between the resistors R63 and R64. The two threshold voltages correspond to the nominal value (HV+/2) plus and minus (+/-) the desired threshold value for asymmetry detection. A comparator COMP1 has its inverting (-) input terminal connected to the node between the resistors R63 and R64 and a comparator COMP2 has its non-inverting (+) input terminal connected to the node between the resistors R64 and R65. The non-inverting (+) input terminal of the comparator COMP1 and the inverting (-) input terminal of the comparator COMP2 are connected to a node between the resistors R61 and R62. The outputs of the comparators COMP1 and COMP2 are connected to the input of a NOR gate G1. The NOR gate also has an input connected to the "OR"ed outputs Q11, Q12, Q13 of the counter CTR. The output of the NOR gate G1 is coupled to the base of bipolar switch Q21. The collector of switch Q21 is connected to the RS terminal. The collector is also connected to the CT terminal via resistor R57 and capacitor C55. The collector is further connected to the RT terminal via resistors R57 and R58 The emitter of switch Q21 is connected to ground in the same manner as in Fig. 5B.

The end of life detection means operate as follows. When the DC voltage at node M1 is above the high threshold voltage, the output of the comparator COMP1 will be high and if the DC voltage at node M1 is below the low threshold voltage, the output of the comparator COMP 2 will be high. Either situation corresponds to a DC voltage across the lamp due to asymmetric operation being greater than the selected threshold. Whenever either of the outputs of COMP1 or COMP2 are high, the output of the NOR gate G1 is low, switch Q22 is open, and the counter CTR counts up. After the time threshold value the "OR"ed output of the counter CTR becomes high, closing the mosfet switch Q22. The drain QD of mosfet Q22 is connected to ground and the source QS is connected to the base or control gate of one of the inverter switches S1, S2. Alternatively, the source of switch Q22 may be connected to a control or power supply input of a control circuit for the switches S1, S2. For either case, the switch Q22 when conductive prevents inverter oscillation and extinguishes the lamp. The circuit provides the same hiccup operation as in Fig. 5B. It is also possible for the output of the NOR gate G1 to be connected to a control or power supply input of a

control circuit for the switches S1, S2.

While there has been shown to be what are considered to be the preferred embodiments of the invention, it will be apparent to those of ordinary skill in the art that various modifications can be made without departing from the scope of the invention as defined by the appended claims. Accordingly, the disclosure is illustrative only and not limiting.

CLAIMS:

1. A power supply for feeding and igniting a gas discharge lamp, said power supply comprising:

a) input terminals (K1, K2) for connection to an AC mains supply having a mains supply frequency,

b) output terminals (T1, T2) for connection to a gas discharge lamp having a pair of discharge electrodes between which a column discharge is maintainable during lamp operation,

c) ballasting means (K, L, M, N) connected between said input terminals and said output terminals, said ballasting means providing an AC voltage at said output terminals to maintain a column discharge between the discharge electrodes of the discharge lamp alternately with one polarity and with the opposite polarity at a frequency substantially higher than the mains supply frequency, and

d) end of life detection means (P) for detecting an asymmetric operating state of the lamp in which the lamp current for the column discharge of one polarity is different from the lamp current for the column discharge of the other polarity, and for switching off the lamp if a said asymmetric operating state is detected, which end of life detection means comprise DC-voltage detection means (VD) for detecting a deviation of a DC-voltage from a nominal value due to a said asymmetric operating state,

characterised in that

the end of life detection means (P) further comprise timer means (Ti) which detect an asymmetric operating state if the DC-voltage detection means detect a deviation of the DC voltage from its nominal value for a time duration longer than a threshold time value.

2. A power supply according to claim 1, characterised in that the timer means (Ti) includes means for storing a time value (CTR) when the DC-voltage is no longer detected and for incrementing the time value when the DC voltage is subsequently detected.

3. A power supply according to claim 1 or 2, characterised in that the power supply includes reactivation means (Ti) for igniting the lamp within a predetermined time after the first threshold time value is exceeded.

4. A power supply according to claim 1, 2 or 3, characterised in that said

ballasting means includes a DC source (GND, HV+) having a DC potential, a bridge inverter including a pair of switches (S1, S2) series connected across said DC source, a load circuit (L10, C63, T1, T2) including output terminals (T1, T2) for the discharge lamp, said load circuit having a first end coupled to a node (M2) between said switches and a second end, a half bridge supply capacitor (C61) coupled to the DC source and said second end of said load circuit, and means for switching said switches to generate an AC signal across the discharge lamp, said switches being switched such that the DC-voltage at said second end of said load circuit has a nominal value in a non-asymmetric operating state of the lamp equal to one-half said DC potential, said detection circuit (VD) detecting the deviation of the DC-voltage from the nominal value generated by said asymmetric operating state of the lamp.

5. A power supply according to claim 4, wherein the detection means includes means (R63 - R65) for setting a high threshold voltage equal to said nominal value plus a DC threshold value and a low threshold voltage equal to said nominal value minus said DC threshold value, means (COMP1, COMP2) for comparing the DC voltage at the second end of said load circuit with said high and low threshold voltages, and means (G1) for outputting a control signal when the DC voltage at said second end of said load circuit is higher than said high threshold voltage or lower than said lower threshold voltage.

6. A power supply according to claim 1, 2, 3 or 4, characterised in that the DC-voltage detection means (VD) comprise means for determining the magnitude (D30-D31) of deviation of the DC-voltage from the nominal value and means (D34) for comparing said magnitude with a threshold voltage, and for outputting a control signal when said magnitude is higher than said threshold voltage.

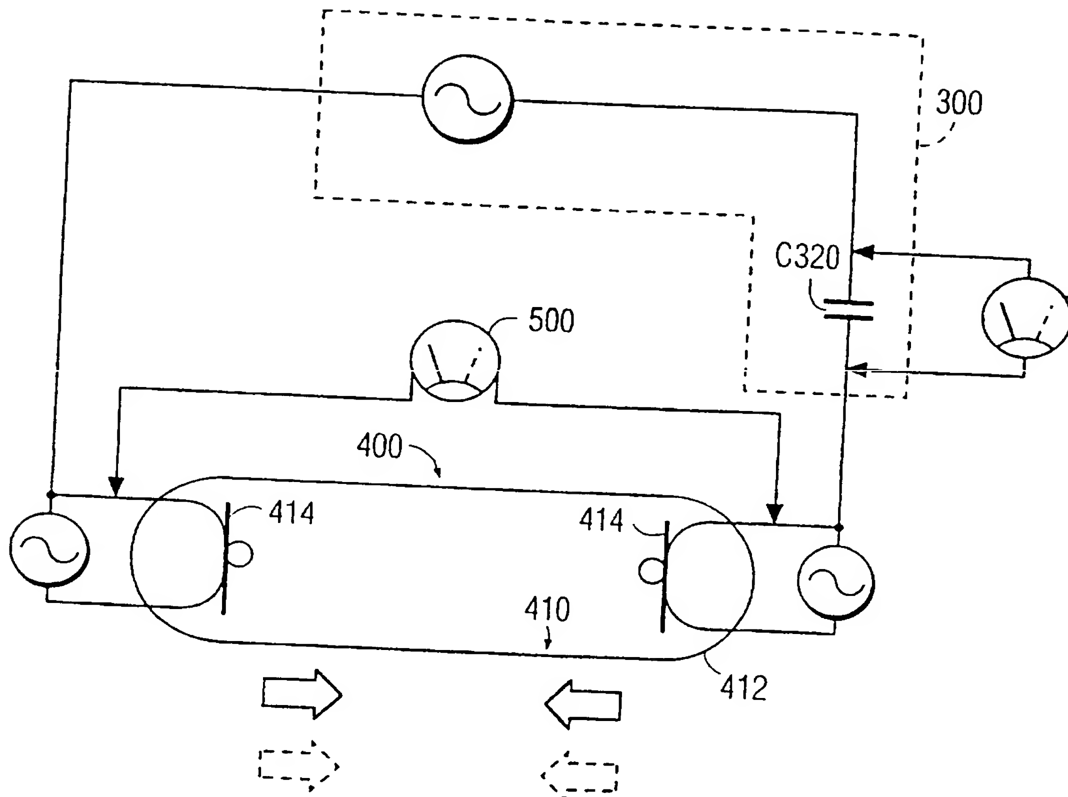


FIG. 1

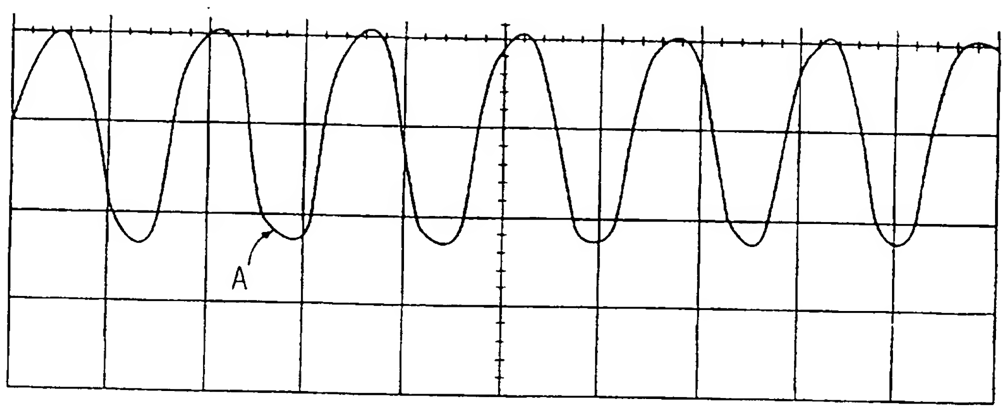


FIG. 2

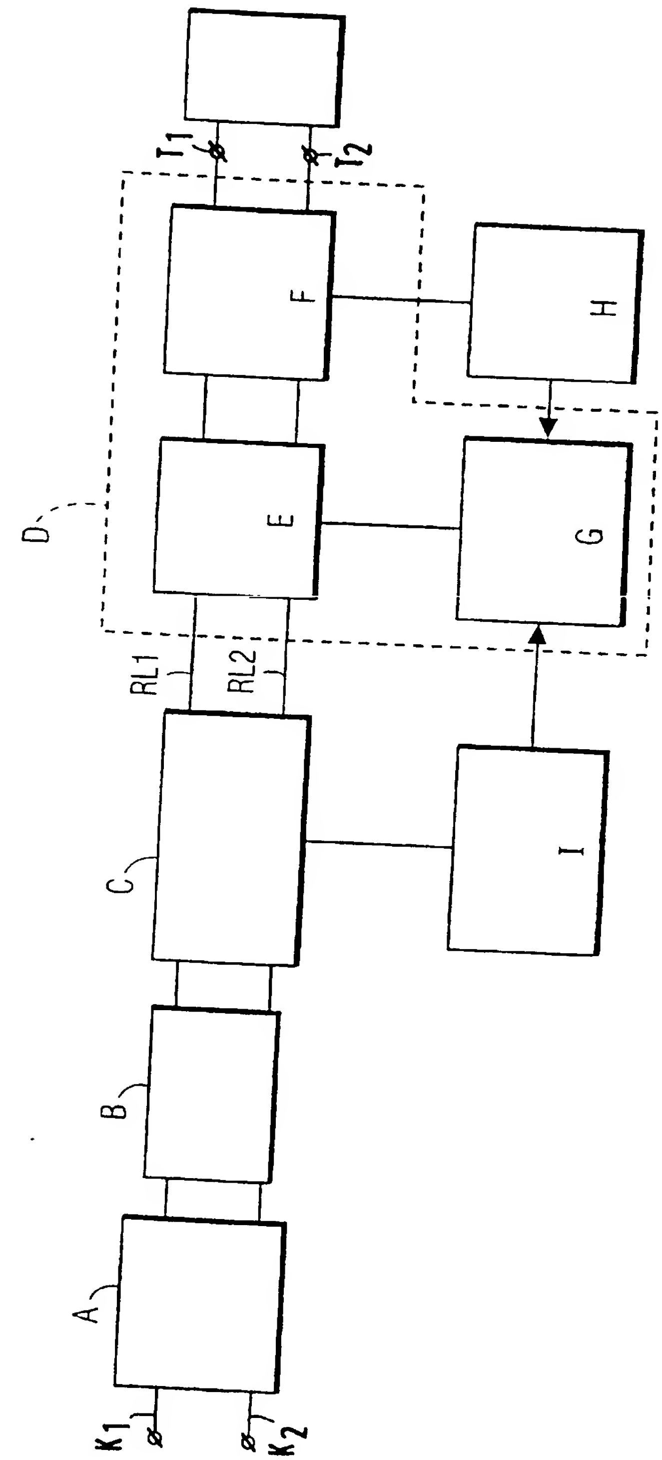
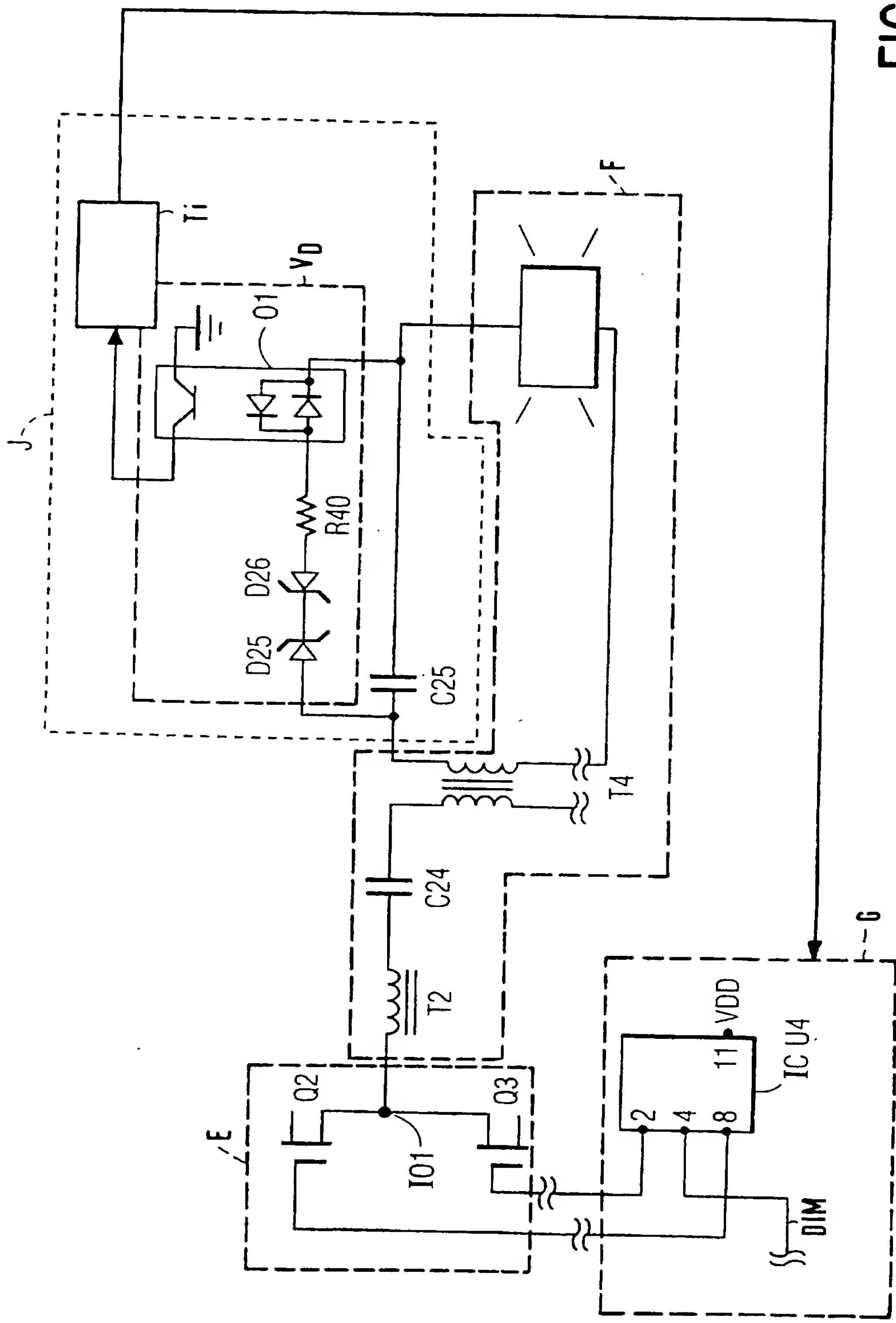


FIG. 3

FIG. 4


Ti
VD
O1
J
F
R40
D26
D25
C25
T4
C24
T2
G
VDD
11
IC U4
2
4
8
DIM
Q2
Q3
E
IO1

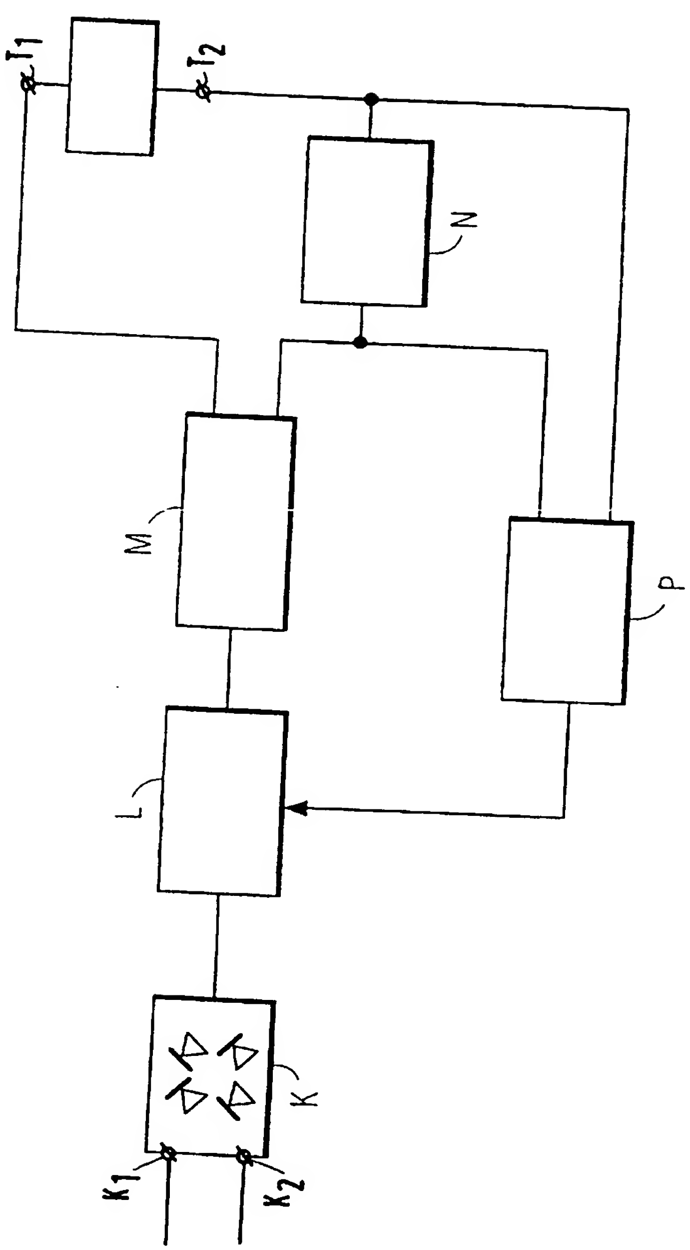


FIG. 5A

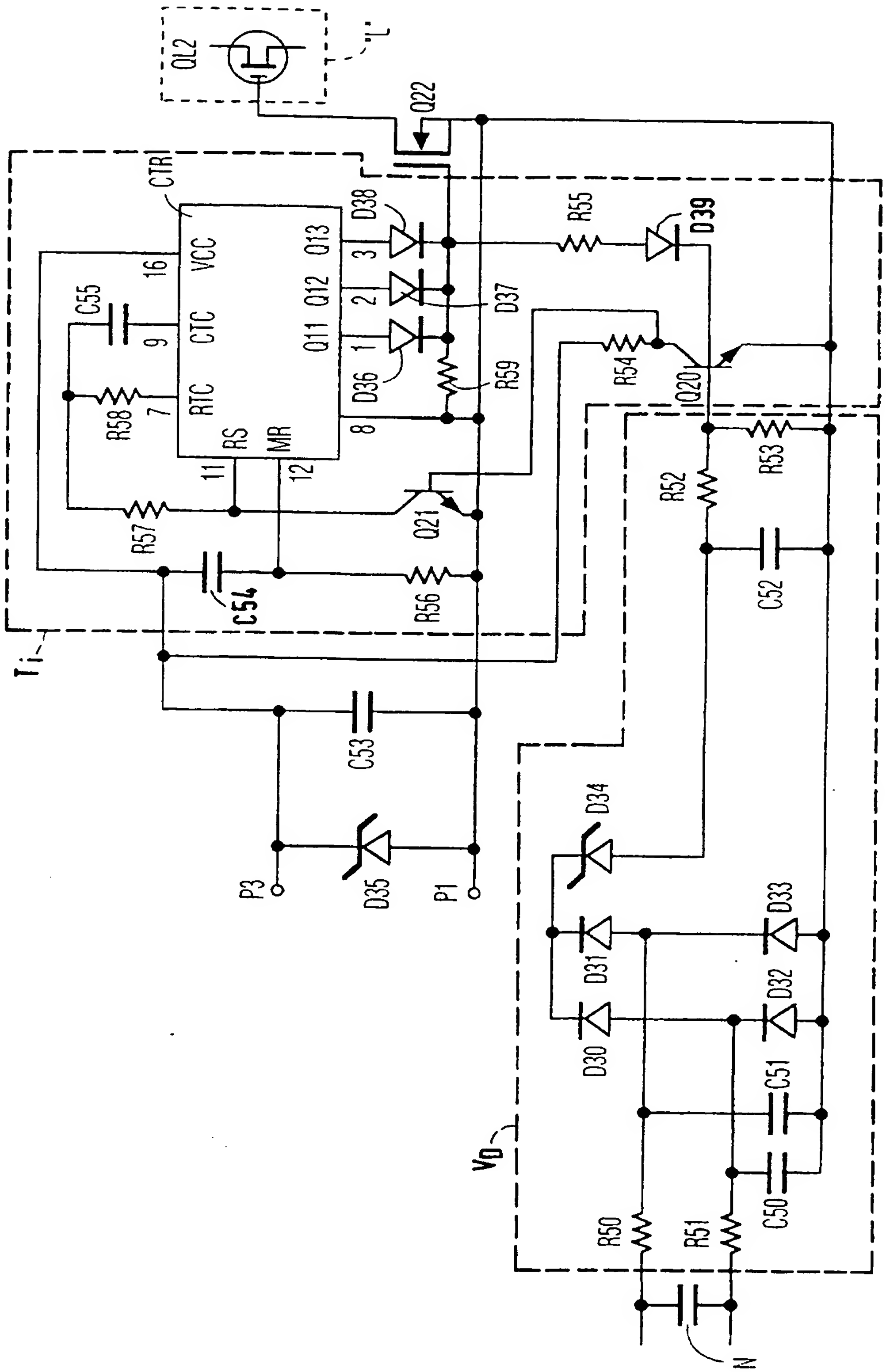

QL2
Q22
CTRl
VCC
CTC
RTC
RS
MR
Q13
Q12
Q11
16
9
7
11
12
8
3
2
1
C55
R58
R57
C54
R56
D38
D37
D36
R59
R55
D39
R54
Q20
Q21
R53
R52
C52
C53
D34
D35
P3
P1
D33
D31
D32
D30
C51
C50
R50
R51
Ti
V_D
N

FIG. 5B

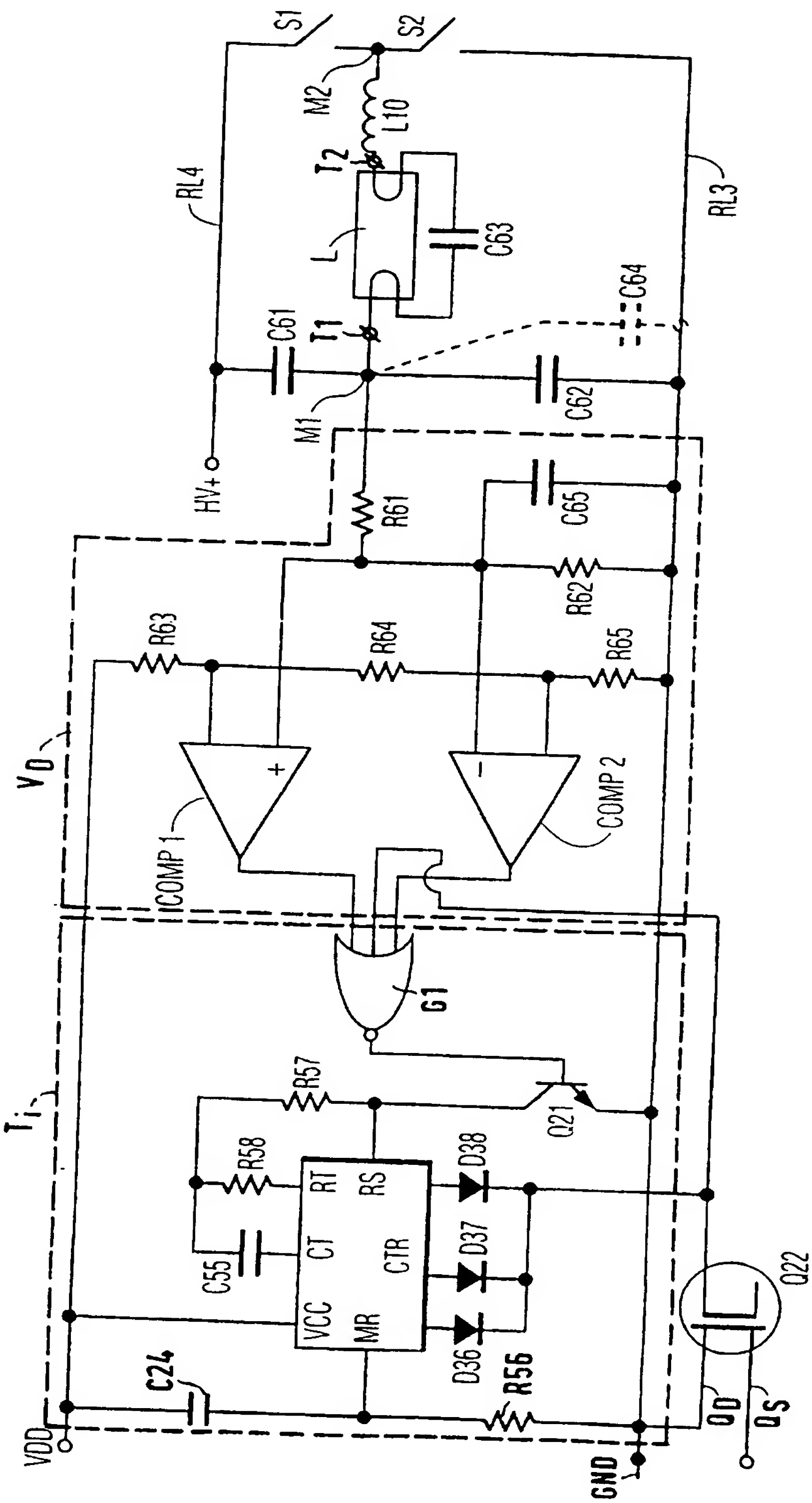

S1
S2
M2
L10
T2
RL4
L
C63
RL3
C64
C61
T1
C62
M1
HV+
R61
C65
R62
R63
R64
R65
V_D
COMP 1
COMP 2
G1
R57
Q21
T_i
R58
RT
RS
D38
C55
CT
CTR
D37
Q22
VCC
MR
C24
D36
R56
VDD
GND
Q_D
Q_S

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB 97/00482

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H05B 41/29

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Patent Abstracts of Japan, Vol 17,No 35, E-1310, 22 January 1993 (22.01.93), abstract of JP,A, 4-255696 (STANELY ELECTRIC CO LTD), 10 Sept 1992 (10.09.92) --	1-6
A	US 5493180 A (R.J.BEZDON ET AL), 20 February 1996 (20.02.96), column 7, line 17 - column 9, line 60, figures 3-7 --	1-6

☐ Further documents are listed in the continuation of Box C.　☒ See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" erlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 October 1997	13 -10- 1997
Name and mailing address of the ISA/	Authorized officer
Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Bertil Nordenberg Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB 97/00482

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5493180 A	20/02/96	WO 9631093 A	03/10/96

Form PCT/ISA/210 (patent family annex) (July 1992)